IMPLEMENTING LEAN MANUFACTURING TOOLS IN A SMALL MANUFACTURING ENVIRONMENT

by

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ABSTRACT

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With the steadfast competition among companies trying to out do one another in order to sustain or establish market shares, many companies look for ways to establish shorter lead while producing a quality product at a competitive price. This brings about the idea of improving process through concepts of lean practices.

This study was conducted in order to demonstrate a kind of environment applicable to lean philosophies and show some of the benefits that can be obtained by implementing them. This study takes place in a small manufacturing environment where minimal logical procedural improvements have been done in the past. Lean tools and concepts were introduced to the company XYZ in order to create a system in a working environment that promotes a mentality of lean thinking and ongoing continuous process improvement. Areas within the company were identified where lean tools could be the most beneficial in the elimination of non-value added activities. Lean tools were then applied and implemented to these areas with future plans of expanding the lean philosophy throughout the company. The lean tools that where used and implemented in the study was kanban, 5S, point of use storage (POUS), batch reduction, cross-training / teamwork, and layout and flow. This study can be helpful to engineers, managers, and executives that are making plans for future implementation of lean practices.

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CHAPTER ONE: RESEARCH PROBLEM AND OBJECTIVES

Introduction

This field project was completed at XYZ Company located in Saint Paul, Minnesota. The project employed the lean manufacturing tools of reduced batched sizes, POUS, standardized assembly, cross training of employees, redesign of layouts, and a kanban pull system. This implementation was done to increase productivity in the company's "Visual Camera" line. This study examines the current production process by discovering and reducing non-value added activities as well as other alternatives that will improve the production process through reduction of the work-in-process inventory (WIP), provision of a visual management schedule system, and creation of a more efficient reorganization of the work area.

Overview of this Thesis

This chapter states the introduction to the thesis, including the background, problem statement, objective, significance, and limitations of the study. Chapter Two reviews the history and the most current literature available concerning Lean manufacturing and some of its tools. Chapter Three outlines in detail the research methods used in this study. Chapter Four presents the results of the study. Chapter Five performs a complete analysis of the study, drawing conclusions and recommendations for future research.

Statement of the Problem

The problems found on the "Visual Camera" line at company XYZ were excess inventory, poorly identified parts, material flow interruptions, unavailability of needed parts, inaccurate part ordering, and not meeting lead times.

Objective of this Study

The objective of this study is to apply Lean concepts and tools that will eliminate non-value-added activities and produce a more efficient flow of production in the "Visual Camera" line in order to handle the line's increasing project growth while being able to adapt to the changing needs of the customer.

The goals of having a Lean system established to:

1. Minimize risk of inventory obsolescence
2. Establish a system of part identification
3. Create visual scheduling and visual management of the process
4. Place control at the operations level
5. Improve flow
6. Prevent over production
7. Decrease floor space utilized by the "Visual Camera" line
8. Increase inventory turns

Significance of the Study

The study will benefit company XYZ and any other manufacturing company considering an increase in throughput by reducing batch sizes, using cross training, creating visual inventory scheduling, and developing a more efficient process layout with a pull system.

Some of the benefits that will be achieved through the implementation of this study are a:

1. Reduction in labor

2. Reduction in lost inventory

3. Improved inventory ordering system

4. Increase in production

5. Cleaner and safer work area due to the elimination of excessive WIP

Limitations of this Study

1. Findings are limited and applicable only to the company covered in this study.
2. The study is intended to demonstrate the process and experiences involved in setting up a Lean manufacturing system. It is not intended to show the final results of a fully implemented system. A full implementation would require more time then the study was allowed.
3. The study is not meant to go into full detail of the set up of a Lean but rather to an idea of the issues and situations that may occur during its implementation.

Assumptions

1. The individuals involved in the study are ensured that changes to their production system are an attempt to improve the system.
2. The workers in the "Visual Camera" line will provide fair and honest answers to questions.
3. The company will not make significant changes to its production system during for the duration of this study.
4. Workers and management will be cooperative in providing accurate information.
5. Training will be provided for employees, not only to assist in learning new process methods, but also to build ownership and involvement to any newly developed process improvements.

6. The company will continue to use the same equipment for production.

Delimitation

This study will not analyze gender or age as a method of evaluation. The study will be limited to management, the supervisor of the department, and workers involved assembly operations at the company's "Visual Camera" line. Workers and/or management will not be evaluated based on knowledge, skills, or abilities of assembly prior to training.

Definition of Terms

Batch Processing: Method of running a quantity of parts at one operation before moving them to the proceeding operations.

Single piece flow: Producing one unit at a time, as opposed to producing in large lots, as in Batch Processing.

Constraint: Anything that limits the system from attaining its goal. Constraints may be categorized as behavioral, managerial, capacity, market, and logistical. System constraints determine the maximum amount of system throughput.

Finished goods: Storage area where parts in their completed state are stored prior to shipping. Parts that customers require on quick notice usually are stored in finished goods.

Lead time: The length of time it takes between an order being received, and the finished product being shipped to the customer.

Purchasing: The department that is responsible for buying raw materials.

Workers: Individuals involved in providing the assembling operation are known as workers.

Work in process (WIP) inventory: Any product still undergoing the manufacturing process and is in transformation from raw materials into the final product.

Raw Materials: Material that is purchased and has not begun any transformation from its shipped stage.

Flow manufacturing: A manufacturing methodology that pulls items from suppliers through a synchronized manufacturing process to the end product. The principle goal is faster response to customer demand.

Kanban: The Japanese word for card, also a type of communication that is associated with Lean manufacturing. In manufacturing, kanban is typically used in reference to a stocking technique using containers, cards, and electronic signals to make production systems respond to real needs rather than predictions and forecasts. It is designed to create a pull system of manufacturing.

Kaizen: Japanese term for incremental improvement. A team approach to quickly tear down and rebuild a process layout to function more efficiently.

Poke -Yoke: Techniques used in manufacturing processes to mistake-proof those processes.

Mistake-proofing: any change to an operation that helps the operator reduce or eliminate mistakes.

Just-in-time (JIT): A manufacturing method where downstream operations pull required parts needed from upstream operations at the required time. Implementing JIT requires most features of Lean manufacturing.

Lean manufacturing: A production method that is aimed at the elimination of waste in every area of production including customer relations, product design, supplier networks and factory management. Its goal is to incorporate less human effort, less inventory, less time to develop products, and less space to become highly responsive to customer demand while producing top quality products in the most efficient and economical manner possible.

Value-added: A procedure of adding a part, customization, and/or service to a product in order to increase the value of that product.

Non-value-added: Any procedure and/or movement of a part that does not increase the value of that part.

Part/subassemblies: Any part, combination of parts (subassembly), or combination of subassemblies that go into the creation of a complete visual camera.

Safety stock: An extra amount of inventory above the normal or predicted amount of inventory used that is kept to ensure the cover of any unpredictable rising need for inventory.

Bottleneck: A process or procedure that slows down or impedes the smooth flow of production. It can usually be recognized by the back-up or build-up of inventory or WIP behind a machine or operation.

Bill of material (BOM): A list of material or parts that are needed to complete a product or a subassembly of a product.

Abbreviations

1. WIP: Work in process

2. JIT: Just-in-time

3. MIT: Massachusetts Institute of Technology

4. BOM: Bill of materials

5. TPS: Toyota Production System

6. POUS: Point of use storage

7. 5S: a Lean tool used in this project that encompassing S1, S2, S3, S4, and S5

8. S1: Part of the 5S representing the term sort

9. S2: Part of the 5S representing the term set in order

10. S3: Part of the 5S representing the term shine (inspect)

11. S4: Part of the 5S representing the term standardize

12. S5: Part of the 5S representing the term sustain

13. DFM: Design for Manufacturability

CHAPTER TWO: LITERATURE REVIEW

The purpose of this project was to create a system that results in shorter lead times, and higher quality, while allowing for additional future improvements of a specific line within a manufacturing company. This chapter provides a historical background on Lean manufacturing and some of the tools that comprise the Lean manufacturing process.

Before the 1900's, if you wanted to produce something you would have to visit a craft producer or skilled tradesperson, employing the typical method of product creation of the time, known as craft production. This person was required to be proficient in a wide range of manufacturing techniques. The tradesperson would take the specifications for an order that you needed and several months later they would ask you to test the product with them, ensuring it worked the way you wanted. This product would be one-of-a-kind, with a high cost attached to it. However, you would have had the benefit of direct producer contact. Craft production utilized a work force of skilled trades people using general-purpose machines that produced at low volumes with high prices. Since each product was a one-of-a-kind prototype without any production cycles, which would otherwise allow for improvement in design or creation technique, product quality was very low.

In order to drive down price and build a larger customer base, the concept of mass production was introduced. Three key people who helped in the industry-wide establishment of mass production were Fred Winslow Taylor, Henry Ford, and Alfred Sloan.

Taylor contributed his advances by applying the scientific principle to manufacturing (Taylor, 1908). Based on the applied scientific principle, Taylor tried to identify the best way complete a given job within a process. He used time and motion studies for developing a way of standardizing work. Once standardized work processes had been established, he used measurement and analysis to improve the process continuously. These methods were revolutionary at their time; operators were instructed to complete short repetitive tasks, that didn't require thinking for themselves.

Henry Ford wanted to produce an automobile that anyone could afford (Cammarano, 1997). To accomplish this, he needed to design a product that was easy to manufacture and repair. By creating interchangeable parts and a simple assembly process, Ford was able to take the template of the disassembly line used in the slaughterhouses in Chicago, and the conversely apply it as an assembly line in the automobile manufacturing industry (Womack, Jones, and Roos 1990). Using this manufacturing innovation, Ford was able to sell automobiles at such a low price that his sales volume skyrocketed to two million automobiles in one year.

With this newly introduced philosophy of mass production, a need for new managerial and marketing innovations arose within these now large-scale corporations. Alfred Sloan of General Motors answered that call (Womack, Jones, and Roos 1990). As part of these innovations, the corporation was divided into divisions, and each division manager reported to a corporate office. To accommodate this new style of management, generally accepted accounting practice (GAAP) was established. This new accounting method encouraged wasteful manufacturing practices of building up inventories rather than meeting customer demands. This style of management also widened the gap between managers and the shop floor operators.

Taylor's scientific system, Ford's manufacturing innovations, and Sloan's marketing and management techniques added to the development of the concept of mass production. Customers were able to purchase once-expensive products at lower costs, because they were produced in high volumes. Despite this benefit to the consumer, mass production also had its problems. It broke down processes into small, simple, and mindlessly repetitive tasks that did not allow operators to utilize creativity and empowerment in their jobs. Workers began to hate their jobs. Soon unions were established, contributing to a reduced sense of partnership between the company and its workers. Workers also withheld information that might have improved the process of production. Production was gauged by accounting practices rather than customer demand, resulting in high production volumes that were necessary to cover the costs of large and expensive production equipment. Also, production was prioritized over quality because it was more important to keep the production flow going at the time of a noticed defect, then later investigate and eliminate the cause of the defects. End of the line inspection became the norm with many companies. Using end of the line inspection with mass production allowed many defective parts to be produced before the defect was discovered, even a defect that may have originated in the initial steps of production.

In 1950, Eiji Toyoda of Toyota visited Ford's Rouge plant, the most efficient plant of its time. He discovered that mass production would not work in Japan and that there were improvements on the system that could be achieved. Japan had a small domestic market for automobiles that required a wide range of vehicles including small and large trucks, expensive luxury automobiles, and smaller, fully efficient automobiles. Because it was a post war-torn country, Japan was starving for capital. The large amount of financial investment, all necessary to obtain the needed technology for these processes, was unavailable. Competition was also furious. Automobile makers around the world wanted to establish their own market shares within Japan's market. Needing to produce a variety of products at low costs, not having a large amount of investment capital, and wanting to give workers empowerment in the production process, Toyota decided to take mass production and improve it. This brought about the concept known today as the Toyota Production System (TPS).

TPS is a rational and cost effective manufacturing system that allows production of many different styles and types of automobiles in small lots, while still meeting the requirement of short lead times. It refines the art of eliminating wastes that are not necessarily apparent to an everyday observer. Tools such as kanban, poke-yoke, kazian, 5S, JIT all contributed to bringing TPS to life.

The book Japanese Manufacturing Techniques (Schonberger, 1982) explains how the Japanese use an altogether different, more effective manufacturing system than typical North American manufacturing systems. Engineered by TPS and built around continuous piece flow, JIT production and delivery, waste elimination, and other simple principles, these manufacturing systems are now recognized as great innovations in the United States and have been adopted by many major corporations (Lubben, 1988).

In the more popular books The Goal (Goldratt, 1992), The Race (Goldratt, 1982), and Theory of Constraints (Goldratt, 1999), Goldratt talks about the need of reducing cycle time and inventory, increasing throughput, and treating all the manufacturing process as a machine whose output is limited by the bottleneck processes within that machine. Goldratt recognized the gains of using TPS as the main process in achieving these goals.

Producing a competitive advantage is essential in today's market (Strickland, 1999). This competitive advantage is ultimately achieved through producing products with short lead times, high quality, and low cost or by providing customers with what they perceive as a superior value. In the past, many companies set their price by taking the cost of manufacturing the product and then adding in the profit margin they wanted to receive. In essence, the manufacturing companies determined how much the customer would pay for the product. With competition coming from all over the globe, customers now determine the price that they are willing to pay for a product and the manufacturing companies have to sell the product at that price while continuing to meet the required profit margins. Price is now in a fixed position; cost is subtracted from the price in order to produce profit. Therefore, the only way to increase profit is through cost reduction. This transfer of who determines the price of product is called channel power (Johnson, 2000). The channel power, which was originally in the hands of the manufacturing companies, is now transferred to the customer. The combination of each of these situations leads up to the current popular practice of Lean manufacturing.

Lean Manufacturing

Lean is a philosophy of waste elimination. It is a continuous on going process of improvement. The term Lean was popularized by Womack, Jones, and Roos (1990) after completing a five year MIT research project where they found several successful companies that used a method of production based on the TPS (Shingo1989, Ohno 1988). Lean production, sometimes know as the TPS, means doing more with less-less time less space, less human effort, less machinery, and less materials-while providing customers what they desire in the finished product (Denis, 2002).

This philosophy is backed up by Womack, Jones, and Roos (1990), who believe that Lean thinking in the twenty-first century will dramatically boost productivity, while reducing errors, accidents, space requirements, production time, and cost.

The basics of running Lean manufacturing come from the concept of "pull". The term "pull" comes from the following idea: no upstream step in the manufacturing process should produce a good or service until the customer downstream asks for it (Dennis, 2002). Product is only produced by the manufacturer when there is a need for it. This is opposite of the conventional mass production use of the term "push". When following the concept of "push", production scheduling is based on a projected demand. Product is made in large batches because of costly, extended changeover times. Inventories are kept at high levels because of the necessity of producing in large batches, as well as the need to be prepared for an occasional unpredictable jump in actual demand, compared to the originally forecasted demand. Storage space eventually begins to dwindle, bringing in the need for larger facilities with more material handling equipment and operators. Having a large facility with large batches confines operators and obstructs communication, preventing a manufacturing system from having an efficient flow.

Womack and Jones (1996) found some common benefits achieved by companies around the world when they converted from a batch and queue production system to an effective pull continuous flow system that is triggered by customer demand. Some of the found benefits were that labor productivity was doubled throughout the system and production throughput times were cut by 90%. Inventories within the system were reduced by 90%, errors reaching the customer and scrap within the production system were cut in half, and time-to-market recorded for new products was cut in half.

The following descriptions are tools used in the Lean manufacturing philosophy presented in this project:

Kanbans

Kanban is a key tool that is used in the Lean philosophy. It is a system of visual tools that synchronizes and provides instruction to workers, suppliers, and customers both inside and outside the plant. A kanban usually consists of a signaling device such as a card or empty container. The system is designed to free up material planners, schedulers, and supervisors so they are able to immediately manage exceptions that may occur, thereby improving the process (Gross and Mcinnis, 2003). It also empowers the operators to make operational decisions, placing control at the value-added level. The best kanban system, however, is to have no kanban system at all, meaning that kanban is only a substitute to implement a single piece flow within a process.

When a kanban system is properly implemented and operated at its fullest potential, it results in many improvements. It reduces inventory by matching production to actual demand, as well as improving production flow by signaling the operators precisely what to produce and when to produce it. Overproduction is prevented by assigning the exact number of parts that should be placed in a container. The kanban system places control at the operator level by having visual production signals at the production floor, improves responsiveness by allowing order status to be changed at production speed, and guarantees an uninterrupted supply of parts without needing forecasting or detailed ordering procedures (Anderson, 2004).

A typical kanban system that is applied throughout the entire manufacturing process can be classified into five different sections (Society of Manufacturing Engineers, 2004). These sections are customer, shipping, assembly, supermarket or storage, and the supplier. Each section pulls on the upstream section for it product. The customer section pulls product from the shipping section, which pulls from the assembly section. This process continues all the way upstream to the supplier.

In a production setting, there is a fixed or controlled level where finished goods are pulled from to match incoming orders from the customer. Kanban containers can be used to match the rate of customer orders to the upstream production, thereby creating a fixed inventory throughout production system. Safety stock can be simply determined by multiplying the number of containers on hand by the capacity of each container. If employees are instructed only to produce as much as the kanban container can hold, then inventory will never ascend above the safety stock level. As soon as the container is emptied by an order, the emptied container acts as a visual signal to the workers to produce more product until the container is full. The inventory level is set by the number of containers within the production system. Inventory and WIP levels can either be increased or decreased simply by adding more containers to the system.

5S

5S is a stability tool that creates the orderliness of standardized work within the Lean philosophy. It creates a visual workplace where the environment is self-explaining, self-ordering, and self-improving (Galsworth, 1997). The American interpretations of the 5S are sort, S1; set in order, S2; shine (inspect), S3; standardize, S4; and sustain, S5. In the implementation of S1, sort out, items that are not needed again are sorted, classified, and disposed of. During set in order, S2, items are laid out in the most efficient manner that reduces waste. S3, shine (inspect), involves cleaning the work areas in order to raise moral of the operators and to allow for easy identification of problem areas. S4, standardize, means creating uniform and consistent procedures and policies that will maintain high-quality working conditions. S5, sustain, ensures that the 5S's will remain within the culture of the company consistently throughout the life of the company by implementing worker involvement and a feeling of worker ownership.

POUS

Point of use storage (POUS) is another tool that contributes to the benefits of the Lean philosophy. A small number of parts, necessary to the assembly of the product, is stored within an arms reach of the assembly process. A kanban usually triggers the replenishment of parts. POUS complements S2 where the layout allows parts to be stored near the assembly process.

Batch Reduction

Producing a large batch of product at one time was once the norm for mass production. This was done in order to produce at high volumes, which would, in turn result in producing an ultimately cheaper product. Often, this was triggered by a need to cover the cost of a large capital investment, usually expensive machinery. The problem with operating according to this principal was that a large amount of WIP and inventory would build up, leaving many items that might not be needed sitting as waste, or even more costly, completely forgotten about. This WIP and inventory also needed a place to be stored and a method, using a person or a procedure, to keep track of them. Because they were all produced on the same line with the same ingredient parts, the finished parts made in a large batch could potentially contain all the same defects, resulting in a large batch of scrap (Anderson, 2004). Batch reduction reduces scrap, rework, and quality costs, because defects are easily seen and corrective action can be taken before a large quantity of defective product is produced. When batch reduction is implemented, parts are produced in smaller qualities, thereby eliminating the need for excessive parts or the buildup of WIP. Parts will be produced closer to the time when they are needed instead of being produced in large batch sizes that need to be stored. The smaller the batch size, the closer you are to having a true single piece full system, a system with the least amount of WIP and the shortest possible lead time.

Cross-Training / Teamwork

Employees need to be proficient at all of the processes performed in their area (Lubben, 1988). Being cross-trained in their work area allows each new task to be completed efficiently when signaled by the kanban system (Gross and Mcinnis, 2003). This allows the kanban system to flow correctly by eliminating bottlenecks created by the lack of labor. Cross-training empowers workers in their tasks, allowing them to think for themselves and develop feel ownership of the process (Lubben, 1988).

Layout and Flow

To have a more efficient flow and layout is the objective of this section. It has been estimated that between 20% and 50% of total operation expense of a manufacturing facility occurs because of material handling (Salvendy, 2001, pp. 1777). Using a facility with an effective layout can reduce 10% to 30% of these costs.

A more efficient layout redesign will complement the kanban system by allowing product to flow smoothly throughout the process, as well as to be visually interpreted and managed. The usual ingrained mentality of employees is that the current layout of their process is almost impossible to change and improve upon. Some layouts are so old and ingrained in the minds of the employees, that they do not realize how much a change in layout with a reduced travel distance will benefit them. The employees are usually unaware that producing a more efficient flow of product will thereby create less stress and strain on them. Ford states (1922), work that is brought to or placed near the employees reduces the travel time which allows employees to spend more time on value-added work. The company would have the benefits of reduction in non-value-added activities, reduction in the cycle time, and a more efficient use of the floor area.

A way to overcome these problems is to develop a new plant or process layouts, according to Stedman (1998); plant layouts usually need to be redesigned for demand-driven flow systems. A well-redesigned new process layout, one that would among different issues, reduce travel distance and time, represents a more efficient use of the manufacturing space, will help the employees to accept the change.

One of the problems that can interrupt an efficient flow is missing parts needed for production, resulting in not having parts at the exact time they are needed. This does not only drastically increase throughput times, but also, according to Cedarleaf (1994), causes operators that are idle and waiting for work to attempt to keep busy by making partial assemblies and stacking them in huge piles of WIP.

CHAPTER THREE: RESEARCH METHODS

Overview of Problem and Objectives

The company being studied wanted to identify Lean manufacturing principles and apply them to their company in order to increase profitability, flexibility, and capacity.

Research Design

This process starts with identifying current practice and procedures by collecting data at the "Visual Camera" line. The data required to fulfill the objectives was collected in two different ways, participant observation and material gathering. Participant observation is done through watching and asking questions to the employees performing the work on the "Visual Camera" line. Materials are gathered through compiling information from current procedures manuals, process layout plans, policy manuals, and forecasting projections from various sources within the company.

By analyzing the data collected during the project, the researcher and the company will be able to see whether or not Lean tools will provide a valid alternative for improving the efficiency of the "Visual Camera" line. The results presented are created from a compilation of relevant knowledge of the current company situation, the data collected from observation of the production lines, and the researcher's past engineering experience.

Population

The population of this study consists of "Visual Camera" line workers and management personnel from company XYZ. There are six workers who have direct contact with the "Visual Camera" line. Three management personnel are involved in the

"Visual Camera" line. Workers and Management personnel do not spend all their working time on the "Visual Camera" line. Management personnel only spend a fractional amount of their time on the "Visual Camera" line. Workers may also spend time on other lines within the company.

Data Collection Procedure

There were three types of data that needed to be collected in this study to meet the objectives. The first type of data was helped determine where the study's focus should be placed within the company in order to achieve the company's desired full benefit, in the study's limited amount of time. It also determined what type or types of Lean tools should be used to make improvements in those areas.

Some of the questions asked to identify the area of concern:

- Does this area affect many people?
- Is there a concern regarding this area?
- Does improving upon this area have potential for significant time and cost savings?

The ideas of these identifying questions come from the book Experts Systems Applications in Engineering and Manufacturing (Badiru, 1992).

The second type of data to be collected was the final goals for the company. Questions were asked to operators and management concerning the results they wanted obtain. They were also asked how much improvement they desired. Goals were made in order to set the direction of the project, as well as to track its progress. This data also helped to decide what procedures needed to be done and in what order they needed to be done to achieve the desired results.

The third type of data to be collected helped in determining how these Lean tools would fit into the manufacturing process. Current practices of the focus area were observed and methods for introducing and tailoring these new Lean tools to the chosen area were documented.

The types of data came from different sources. There was participate observation where several hours were spent watching and asking employees how and why they where performing the work. Procedure documentation, process layout, and bills of material were gathered to compile a more complete understanding of current processes. Forecasting data and input of the management was gathered to develop an understanding of future potential company growth.

Data Analysis

The company was first asked what it thought were its areas of concern that had an opportunity for improvement. After some discussion, it was decided that the "Visual Camera" line was the area of the company that could benefit the most from this study. Within this line the company wanted to improve flow and reduce lead time. Productivity target/goals were established to see how changes in the line benefited the company XYZ.

Productivity target/goals will be measured according to the following criteria:

1. Layout redesign: The new layout design must have a shorter distance of travel distance then the old. The new layout must have a logical flow that still allows employees to use existing equipment while providing for safety concerns and comfort of the employee.
2. Reduction in floor space: The floor space for the old "Visual Camera" line should be less than the new "Visual Camera" line.

3. Inventory turns: By reducing batch sizes and reducing inventory levels, product should be ordered more frequently. Inventory turns should increase.
4. Cost of goods sold: With the introduction to Lean manufacturing the cost of producing the products should decrease. Cost of goods sold is a percentage of the selling price. As Lean improvements are added to the "Visual Camera" line, this percentage should decrease as long as the selling price remains the same.
5. Shorter lead times: after the establishment of Lean manufacturing on the "Visual Camera" line at company XYX, the lead time on the "Visual Camera" line should be shorter then when the project began.

After looking at the current working methodology used within the "Visual Camera" line, it was decided to use the Lean tools of a kanban visual pull system, 5S, batch reduction, POUS, cross-training / teamwork, and a new layout. These tools would result in the greatest benefit for the "Visual Camera" line while incurring minimal costs to company XYZ.

The kanban tool would be the backbone of directing and commanding the flow of production in the "Visual Camera" line. It would tell the workers which parts to produce and when to produce them. To ensure stability, organization, and cleanliness within the "Visual Camera" line, the lean tool 5S would be applied. The tool POUS makes sure the operators do not waste time retrieving parts from storage. It allows them to spend more time on value-added processes. Batch reduction creates a production flow that is closer to a one piece flow production were WIP and inventory can be greatly reduced. The cross-training/teamwork tool will allow operators to perform multiple tasks up and down the "Visual Camera" line when they are signaled by the kanban to ensure a constant flow of production. A new layout will bring about a more efficient flow of production that is complementary to the kanban tool. It will also allow the extra floor space that was freed up by the reduction of inventory and elimination of obsolete parts to be used for other needs within the company.

Chapter Four: Results

Introduction

The purpose of this study was to identify Lean manufacturing principles and apply them to the company in order to increase profitability, flexibility, and capacity. This chapter presents the overall findings of the study. The beginning of this chapter presents the findings, shows which tools were used and how they were used during the course of the study, the results and benefits obtained from using the tools, and how the tools helped to meet the goals of the study. The end of the chapter lists additional results and findings.

Presenting of the Findings

As mentioned in the previous chapters, the Lean tools used in this project were kanban, 5S, POUS, batch reduction, cross-training / teamwork, layout and flow. Many of the tools overlap and support each other in achieving the goal of eliminating the waste of non-value added activities.

Kanbans

<u>How it is used</u>

Kanbans were used in the "Visual Camera" line to control the flow of production and the amount of inventory or WIP on hand. Bins, containers, and other devices were set up to control the number of parts/sub-assembles produced, as well as to signal the worker when to produce them. Example of bins, containers, and other devices used as kanbans are shown in figures 4.1, 4.2, 4.3, and 4.4. Figures 4.3 and 4.4 show examples of unique kanbans designed to contain a specifically designated maximum amount of product, while allowing the amount of product within the kanban to be seen at a quick glance.

Figure 4.1. Example of kanban

Figure 4.2. Example of kanban

Figure 4.3. Example of kanban

Figure 4.4. Example of kanban

These kanban bins, containers, and other devices were signals to tell the workers what to produce, when to produce it, and how may to produce.

<u>Results and Benefits</u>

The kanbans ensured that parts were ordered when they were needed. Inventory was more easily visually managed, which ensured that extra parts were not ordered, which would have led to extra parts/sub-assemblies sitting around, taking up unnecessary space. The kanbans, along with the 5S, provided the workers and management with the ability to decide which step in the manufacturing process needed to be begun next, by requiring only a quick glance at the "Visual Camera" line. This resulted in producing a smoother visual flow of work.

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With only a quick glance at the kanban bins, the researcher was able to see that production occurred only to the extent of filling the kanban bins; therefore, there were no unnecessary WIP found lying around. In a correctly implemented Lean manufacturing system using kanban tools, overproduction does not occur. The kanban only allows the system to produce a product when it is needed. In summary, WIP and obsolete inventory were greatly reduced.

Here, in figure 4.5, is a kanban for the completed visual camera. Notice that there is only room for two cameras, ensuring that no more then two completed cameras can be produced at a time, thus limiting overproduction. The figure also shows that the kanban, by only having one of the two slots empty, is telling the worker that one more completed visual camera needs to be finished.

Figure 4.5. Two slot kanban holder

with one camera missing

Goals met

The kanbans created the basis for visual scheduling and management of the process. It also helped to minimize risk of inventory obsolescence and prevent overproduction.

5S

How it is used

S1 and S2 were the main components of the 5S that were used in this project. When implementing S1, sort, all parts/subassemblies in the "Visual Camera" line area were sorted through and any unnecessary or unwanted parts were discarded. Then in S2, set in order, parts/subassemblies were organized into specific locations. Each part/subassembly had its own location that was clearly identified with corresponding labels.

Results and Benefits

Discontinued parts were identified and discarded, resulting in cleaner and more organized work areas. These cleaner areas allowed for a smoother flow of work, which created an easily identifiable visual pull system. Before the project, some parts were stored in locations only know by an individual worker. This was especially true for smaller parts. When other workers needed this certain part, they could spend several minutes looking for the part. In one specific instance, needed parts were never found until the worker who stored the part came back from vacation to show other workers where they were stored.

Floor space utilized by the "Visual Camera" line decreased, allowing the newly available space to be utilized by other functions throughout the company. Management did not realize how much space they actually had at their disposal for other line improvements until they started to organize work areas.

Morale of the workers increased when they had a cleaner and more organized workspace. It could be seen quickly that process and procedures were starting to improve. The researcher could sense that the operators and management had already gained a higher feeling of accomplishment and enthusiasm toward the project

Figure 4.6 shows what the work areas looked like before the implementation of the 5S. This original work area was not kept clean and was not organized, two qualities necessary in a work area for promoting an efficient flow of product. Items could easily be lost and it was difficult to discern what needed to be done next.

Figure 4.7 shows a work area that is organized and cleaned after the implementation of the 5s's.

Figure 4.6. Before organization and cleaning using the 5S

Figure 4.7. After organization and cleaning using the 5S

Goals met

The 5S provide the necessary foundation for implementation of other Lean tools. It allowed for the most efficient use of kanbans, which, in turn, helped in meeting the goal of creating visual scheduling and management of the process. The cleaning and reorganization of parts helped to meet the goals of improving the workflow and layout within the "Visual Camera" line and decreasing the floor space utilized by the "Visual Camera" line.

More details on this subject are addressed later in this chapter in the section entitled "Layout and flow".

POUS

How it is used

POUS is used throughout the visual camera line. Every part/subassembly is stored right next to or within an arms-reach of its assembly process on the "Visual Camera" line. These POUS areas are either a kanban container or another device that is clearly labeled with the part/subassembly. Some parts/subassemblies have two locations. One location is

POUS along the visual camera line. The other location is the main storage area. Parts are stored in the main storage area when the order size, which is governed by the vendor, is so large that there is not enough room to store all of the parts directly along the "Visual Camera" line.

Results and Benefits

POUS allowed the workers to spend more time on value added tasks of producing visual cameras. Time was no longer wasted in retrieving and looking for the needed parts to continue the assembly process.

Goals met

By placing the parts/subassemblies near the assembly process, the goal of improving flow was achieved. The non-value added activity of transporting parts/subassemblies from the storage bins to the assembly tables was eliminated, which resulted in an estimated reduction of 39 seconds of travel time per part.

Figure 4.8. Before POUS

Worker needed to get parts

Figure 4.9. After POUS

Parts are stored at assembly area

Figure 4.8 shows how areas looked before the implementation of the 5S and POUS tools. Not all products were stored right next to the assembly process. Workers needed to get up from their assembly areas to retrieve parts/subassemblies need in their production process. With the implementation of the Lean tool POUS, parts/subassemblies are stored in bins that are an arms reach away from the assembly process, as shown in Figure 4.9.

Batch reduction

How it is used

The amount of a certain part/subassembly a worker produces at one time depends on the batch size. The batch size of each process of part/subassembly in the "Visual Camera" line is controlled by the kanban or by how many parts/subassemblies are designated to that kanban container. The number of parts/subassemblies in a batch is produced at the smallest logically possible amount to create a constant flow of product through the "Visual Camera" line.

Results and Benefits

The workers were taught to produce parts/subassemblies in smaller batch sizes. Overall, there was not a great reduction in batch size when producing most of the part/subassemblies on the "Visual Camera" line. This was because the demand on the "Visual Camera" line was to produce approximately one visual camera per day so batch sizes were already set at small quantities.

It was found that one of the most critical factors affecting the batch size was the adhesive glue curing time. Because of the long curing time required, it was necessary to have larger batches for this process. All other batch sizes could be reduced between two to four parts/subassemblies per batch.

After implementation of batch reduction, the researcher noticed that the workers had a firmer grasp on what parts/subassemblies they had on hand. Because of the smaller batch sizes there were, in addition, smaller amounts of WIP and inventory lying around. This helped to reduce the confusion resulting from not knowing whether certain parts were available or not.

Some of the workers were not easily convinced that the concept of producing products at smaller batch sizes was effective. When the researcher left the project, some of the workers still thought it was a waste of time to only produce one or two part/subassemblies at a time.

Goals met

Inventory turns is one way to see whether or not product is being produced in small batches. When product is produced in a small batch there is less inventory on hand, creating a constant flow of inventory into the production system, thus resulting in higher inventory turns. It also shows that the kanban is triggering the pull of a more constant flow of parts into the system. According to the book World Class Manufacturing: The Next Decade (Schonberger, 1996), inventory turns is a great way to see if a company is managing its processes correctly. Low inventory turns indicates that excess inventory is being piled up somewhere in the production process. As expected, Lean manufacturing, with the use of the kanban and batch reduction tools, increased inventory turns. The goal of increasing inventory turns was met. Before this project began, inventory turns was 3.87 turns per year. At the conclusion of this project, inventory turns increased to 8.71 turns per year.

Cross-training / Teamwork

How are they used

Workers were trained to be able to complete different aspects of the assembly work throughout the "Visual Camera" line. Every worker was taught to be familiar with each operation of the "Visual Camera" line and became an expert in four more operations than each worker had originally been an expert at. Each worker was told that he or she was the expert of the operation and possessed the best possible knowledge for improving the flow and operations of the "Visual Camera" line.

Results and Benefits

With the system in place, workers are now able to decide on their own which operation needs to be done. Workers no longer need to rely on a supervisor or management personnel to make each decision, therefore valuable time or both the worker and management is no longer wasted. The cross-training of workers also allows each of them to have control at his or her level. Workers now have the ability to perform multiple operations within the "Visual Camera" line. When a kanban signals that a certain operation needs to be done, the worker has the knowledge and experience to go over to that operation and complete it. The resource, the worker, is able to go where he or she is needed next. The cross-training also allowed the workers to develop a sense of ownership and a desire toward continuous improvement of the whole product being produced, rather than the original focus on their own prior individual processes.

Goals met

Cross-training allowed the worker to float freely throughout the "Visual Camera" line from one operation to another. This helped in placing control at the operations level, meeting another goal of the project. Workers had the power and ability to determine what operation needed to be done next, thereby controlling the flow of products throughout the "Visual Camera" line.

Layout and flow

How it is used

A new layout was used to increase flow and organization within the "Visual Camera" line. Operations within the "Visual Camera" line were rearranged in a logical order that best fit the product assembly. The operation arrangement was in the shape of a "U" to reduce the traveling distance from one operation to the next. New ergonomic production tables with overhead lighting and a backboard to hold the kanban containers were purchased. Storage and kanban containers were rearranged to provide a more efficient use of space. Parts/subassemblies were given designated storage locations.

Results and Benefits

There were other Lean tools that supported using the Lean tool of layout and flow. POUS contributed to the new layout design. Parts that were used in the assembly of the product are now stored in the assembly area. This eliminated the worker's need to leave the work area and look for parts, wasting time that did not add value to the product. 5S's also contributed to the layout. S2, set in order, emphasizes arranging items in a way that produces a smooth flow. New tables and bins were purchased to produce a work environment that was more contingent to a smooth and efficient flow of product. Before the project began, the layout of the "Visual Camera" line consisted of stations scattered throughout the factory floor, causing some stations from one line to be surrounded entirely by stations from other lines. The new layout uses a U-shaped formation of the workstations to ensure that product production flows easily from one station to the next. Figure 4.10 shows the new layout. Notice the layout of the workstations: right next to one another in a U-shaped formation. The new layout decreased the non-value added activity of part transportation within the "Visual Camera" line from 251 feet to 125 feet, a reduction of travel distance by 50.2%.

Figure 4.10. New layout

Workstation setup in a U-shape

Because of designing a new layout, cleaning up and organizing inventory, and producing in smaller batches, there was a reduction in total floor space needed to house the assembly process. Floor space used in the production of the "Visual Camera" line was reduced by 43%. The main reason for such a large reduction in floor space usage was the better utilization of storage space. Figures 4.11 and 4.12 show an example of the utilization of storage space before and after the new layout implementation.

Figure 4.11. Storage area utilization before new layout

Figure 4.12. Storage area utilization after new layout

Figure 4.13 is another example of poor utilization of storage before the new layout. Here it can be seen the poorly designed racks which have empty storage spaces. It also shows boxes being stored on the floor taking up valuable floor space and restricting flow of material.

Figure 4.13. An example of poorly utilized storage space before the implementation of the new layout

Goals met

The newly redesigned layout provided shorter travel distances for product moving through the "Visual Camera" line, reducing the overall production time. The reorganization of the line reduced the floor space needed in the visual camera by 43%.

Other results and findings

Part identification

Another tool that is not part of Lean tools, but was still used in this project, is establishing a system of part identification. One of this study's key findings was that three different systems of part identification were being used throughout the company, rather than a single set standard for part identification. Because of this, communication between purchasing and floor production was sometimes misinterpreted. Wrong parts were sometimes purchased, causing the production floor to wait for parts. The process of ordering parts from floor production to purchasing also required a large, unnecessary amount of time. Purchasing would have to reconfirm with floor production to make sure they had correctly understood which part was truly needed for production. Production would frequently have to be put on hold, waiting for parts to arrive before the workers could complete the final product, which dramatically increased lead times. In order to create a standard system that was universally understood within the company, a standard system of part identification was established. Products on the "Visual Camera" line were broken down into separate, individual parts. Each of the parts was identified. Not only did this help in establishing a kanban system, but it also ended the unnecessary step of the purchasing department returning to operators for verification of which parts they needed.

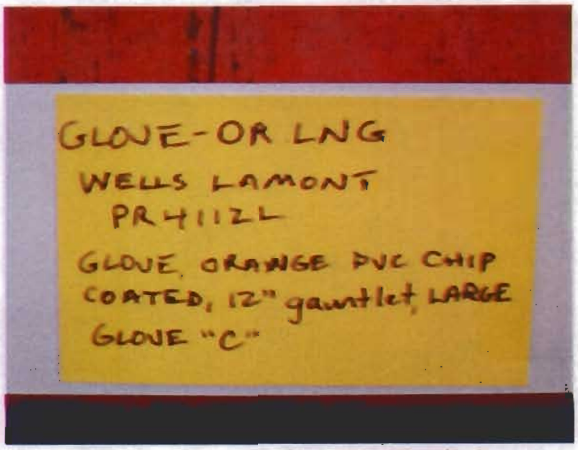

Figure 4.14. Before standardizing part numbers

Figure 4.15. After standardizing part numbers

Figure 4.14 shows an example of how complicated part identification numbers were before the standardization. Simpler more concise part identification numbers were created, as in Figure 4.15.

Improved the accuracy of BOM

Some of the parts that were listed as components of the final product were out of date. In other words, the BOM of the product listed items that were not currently used in the assembly of the products. Errors in the BOM that were discovered in this project were corrected.

Reduced cost of goods sold

The cost of goods sold decreased from 47% to 45% during the time of this project. This meant the cost of producing product on the "Visual Camera" line dropped 3%. This cost savings is expected to increase over time as the workers and management become more familiar with the procedures and processes of Lean.

Reduced lead times

Being able to produce products with a shorter lead time was one of the objectives in implementing Lean procedures in the visual camera line at company XYZ. Because of the time constraint given to this project, it was impossible to gather sufficient data to confirm whether or not shorter lead times were achieved.

Improved flow

Lean manufacturing and its tools improved the overall flow of the "Visual Camera" line. The improved flow resulted not only from the reduction in inventory and floor space, but also from the order created by the kanban and batch reduction. The processes of setting up POUS, standardizing work, and labeling and identifying parts each also helped in providing a better directional flow of moving parts/subassemblies.

CHAPTER FIVE: DISCUSSION

Introduction

This chapter will discuss the findings of the study and compare them to the expected results. It is organized by summarizing the study procedures, presented by restating the problem and restating the limitations of this study, and then following them with conclusions based upon results of the study and recommendations for future studies.

Summary of Study Procedures

Company XYZ felt that processes on their "Visual Camera" line could be improved upon in order to meet lead times and increase efficiencies. This study addressed the methods used to accomplish these outcomes. In chapter one, the research problem of implementing Lean manufacturing tools to the "Visual Camera" line was established, along with a list of objectives the company wanted to achieve. The literature review in chapter two began by discussing the events that leading to the creation of Lean manufacturing and concluded with current documentation of present-day Lean manufacturing practices and a description of some tools involved in the process. Chapter three addresses the procedures of how the data was collected and what types of data were collected and analyzed during the project. Chapter four states which tools were used, how these tools were used, and the benefits that were achieved by using each tool. Each of these chapters build upon each other to support the conclusion and recommendation of this chapter, chapter five.

Restatement of the problem

The problems found on the "Visual Camera" line at company XYZ were excess inventory, poorly identified parts, material flow interruptions, unavailability of needed parts, inaccurate part ordering, and not meeting lead times.

Limitations of this Study

1. Findings are limited and applicable only to the company covered in this study.
2. The study is intended to demonstrate the process and experiences involved in setting up a Lean manufacturing system. It is not intended to show the final results of a fully implemented system. A full implementation would require more time then the study was allowed.
3. The study is not meant to go into full detail of the set up of a Lean but rather to an idea of the issues and situations that may occur during its implementation.

Conclusions

The implementation of Lean manufacturing processes to the visual camera line at company XYZ was an overall success. By implementing the Lean tools of kanban, 5S, batch reduction, POUS, cross-training / teamwork, and layout redesign, some key improvements were made that produced an efficient pull flow of product throughout the "Visual Camera" line.

With the implementation of the Lean tools, many positive results were obtained. The tools of batch reduction and kanban increased inventory turns from 3.87 turns per year to 8.71 turns per year. A redesigned layout, along with the 5S, reduced the required floor space for the "Visual Camera" line by 43%. These tools also helped to decrease distance that the product traveled during assembly by 50.2%. During the course of this project, the cost of goods sold dropped from 47% to 45.25%, with future potential goals of cost of goods sold being low as 32%.

Recommendations

There are four areas that the researcher feels that company XYZ should look into and improve upon. These are the areas of continuing Lean training, appointing a project lead person (champion), implementing production based on Takt time, and improving manufacturability of the visual camera.

These areas are:

1. Lean training

Lean is a continuous improvement philosophy, one that constantly progresses and changes to adapt to markets and conditions, all driven by customer demand. Over time, new, better, and different Lean techniques and technologies will be introduced to the manufacturing industry. Workers will need to be educated in these new techniques and refreshed on current Lean practices. Education of the workers will be the key to the success of Lean. The more educated the workers are on the subject of Lean, the more benefits the company will reap from the Lean philosophy. The workers need to be presented and taught the Lean tools, as well as challenged to change the status quo by performing better today than yesterday. This may even result in the workers coming up with Lean tools of their own.

2. Project champion

This project covered just one line within company XYZ, the "Visual Camera" line. Many other areas within company XYZ have potential for Lean manufacturing improvements. As mentioned in the literature review, the Lean philosophy is not intended to be used merely as a one-time fix, but rather as a continuing improvement process for the whole company, as well as its outside suppliers and customers. In order to ensure this continuation of the Lean philosophy, someone needs to take ownership of and be given authority over the process. Right now there is no one directly responsible for the project and its continuation. The researcher feels that if no one takes responsibility of the continuation of Lean throughout company XYZ, the movement of Lean will come to a standstill. Situations had already occurred during the course of this project where workers and management assumed that someone else was going to accomplish certain tasks, and then when it was checked into, the tasks had not been completed.

Because company XYZ is a small company creating specialized products with a small demand, the workers feel that they are capable of keeping track of parts and items on their own, making Lean tools merely a waste of time. This mentality will make it easy for the workers to revert back to the old way of doing things. To prevent this from happening, the "project champion" would need to show the workers the results they are accomplishing by using the Lean tools on a continual basis. When workers are kept well informed, presented feedback, trained well, and disciplined in using Lean tools, the work and the work environment becomes more enjoyable for everyone. A champion for the Lean movement needs to be appointed.

3. Production base on Takt time

Future process improvements should be based on Takt time. Takt time would help to provide a better understanding of the flow and provide a gauge for further improving upon the setup of workstations within the line. It should also be used to further improve the flow of the "Visual Camera" line. Takt time is the amount of time that elapses between each completed product that comes off the line. The Takt time of the "Visual Camera" line was that one camera was produced for every 8.12 hours of available work time. The following equation represents the Takt time of the "Visual Camera" line.

$$\text{Takt time} = \frac{\text{Total time available} = (6.66 \text{ hours per day})}{\text{Number of products demanded} = (0.82 \text{ products per day})}$$

$$\text{Takt time} = 8.12 \text{ hours per product}$$

The line then should have as many workstations in which the amount of Takt times (8.12 hours per product) can fit into the amount of time needed to complete one product from start to finish (35.4 hours). This is expressed in the following equation.

$$\text{Number of stations needed} = \frac{\text{Labor per product (35.4 hours per product)}}{\text{Takt time (8.12 hours per product)}} = 4.36$$

$$\text{Number of stations needed} = \text{4 to 5 stations}$$

By eliminating some of the non-value activities with in the "Visual Camera" line, the number of stations needed could be reduced from 4.36 stations to 4 stations. The line would then optimally be set up with 4 stations.

The time needed to complete work within a workstation should never be more then the Takt time. Producing according to Takt time ensures that a constant flow of new product will be produced at a rate which will keep up with the customer demand. Takt time was not used in this project.

4. Improve manufacturability

Lean Design, also referred to as Design for Manufacturability (DFM), should be considered for future improvements. Many manufacturing processes within the "Visual Camera" line can be improved upon. Some of the processes involve a lot of repetitive human labor. For instance, one worker spent one whole day cutting up a PVC pipe with a hand hacksaw. By using a mill and a band saw labor could be cut down from one day to a matter of hours.

Many of the parts were being hand-crafted. Some parts were shaped by hand to make sure they could be properly fitted into other parts. Not only is a hand shaped part a one-of-a-kind, custom part that would be hard to replace and exchange, the time and effort required to assemble these parts is long and tedious. Therefore by improving upon the manufacturability of the visual camera, the costs involved in creating or repairing these visual cameras could be greatly reduced, which in turn would help in attaining the goal of decreasing lead times.

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